Using Augmented Reality to Enhance Fire Support Team Training

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ABSTRACT

Live fire training keeps warfighting capabilities at peak effectiveness. However, providing realistic targets for live fire exercises is prohibitively expensive. The United States Marine Corps uses a variety of target proxies in live fire exercises, such as derelict vehicles or piles of waste, which are non-reactive and stay in fixed locations. Augmented Reality (AR) can provide realistic, animated, and reactive virtual targets, as well as special effects such as explosions, for real world training exercises with no significant changes to the current training procedure.

As part of USMC Fire Support Team (FiST) training, trainees learn how to call for fire as forward observers (FO). The FO determines the location of a target and calls for fire. After the round is fired, an instructor determines the effect on the target, and the FO adjusts. Initial FiST training takes place on a scale model firing range using pneumatic mortars, which is where we inserted an AR system.

Our system provides a head-mounted display for the forward observer and a touch screen for the instructor, each showing virtual targets on the real range. The observer can see a simulated magnified view and reticule to determine target identity and location. The instructor controls the targets through a simple interface. The FO calls for fire and a real round is fired. The instructor sees where the round lands in the augmented touch screen view and designates the effect on the target. The forward observer sees that effect and adjusts.

The system was demonstrated at Marine Corps Base Quantico in October 2004, where it was well received by mortar trainees and instructors. The system can also show virtual terrain and control measures. Future plans include testing at a full-scale live fire range like Twentynine Palms and completing a Semi-Automated Forces (SAF) interface for more intelligent targets.

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INTRODUCTION

Live fire training keeps warfighting capabilities at peak effectiveness. However, the cost of procuring real targets—only to be destroyed—is prohibitively expensive. The United States Marine Corps uses a variety of target proxies, such as derelict vehicles, piles of waste, and even “pop up targets,” all of which are non-reactive, stay in fixed locations from year-to-year, and often do not resemble the real targets. Trainees simply do not get the opportunity to fire live rounds at realistic-looking and moving targets. However, Augmented Reality (AR) can help by merging virtual entities with the real world for training exercises. In this article, we describe an AR system that provides virtual targets for training of USMC Fire Support Teams.

Augmented Reality

In an AR system, the user wears a tracked see-through head-mounted display with stereo headphones that is connected to a computer containing a database of spatial information related to the venue of the training exercise. By measuring the user’s position and view direction in the real world, three dimensional computer graphics and spatially located sounds are displayed to appear to exist in the real world. A miniaturized and ruggedized computer, batteries, and wireless networking make the AR system man portable (Julier et al 2000). Figure 1 shows a mobile AR prototype system. In the case of AR for training, the virtual information overlay consists of realistic three-dimensional renderings of entities: individual combatants, tanks, planes, ships, and so on.

Entities in Training Simulations

Entities in training exercises fall into one of three categories: live, virtual, and constructive (USDoD 1995). *Live* entities are real people and vehicles participating in a training exercise; *virtual* entities are human-controlled players in virtual worlds; and *constructive* entities are driven by algorithms in computer simulations. AR provides a natural way for all three types to mix together. Live entities observe virtual and constructive entities through the AR system. Interactions such as the user’s movements and weapon usage are conveyed from the AR system back to the constructive and virtual simulation systems. Fire Support Team Training is a prime venue to insert virtual and constructive entities to combine with live fires.

Figure 1. A Wearable Augmented Reality System

Fire Support Team (FiST) Training

The USMC's Fire Support Team training begins with small-scale (1:40) pneumatic mortars on a 50m x 75m field at Quantico, simulating a 2km x 3km area of operation. The purpose of this training is to hone the communication skills between the forward observer and the Fire Direction Center (FDC). In the current training plan, a forward observer visually locates targets, identifies and determines grid coordinates using binoculars and a map, and recommends a call for fire to the FDC. Once the shots are fired, the training instructor (not a part of the operational fire support team) determines the accuracy of the shots and the effect on the target: catastrophic hit, mobility hit, or no effect. The calls for fire are adjusted until the team has the desired effect on the target. Before introducing the AR system, the team fired upon static and unrealistic proxy targets made of discarded boxes, tubes, and toy tanks.

RELATED WORK

Our application of AR to LVC training is not the first, and others who have developed AR training systems should be acknowledged. One early effort (Barrilleaux 1999), sponsored by US Army STRICOM in 1993, combined live tanks with manned simulators and computer-generated forces. The system was demonstrated in Fort Knox, KY. The tanks equipped with limited AR displays to display the virtual and constructive forces in the world and with instrumentation to send telemetric data back to allow representation in the virtual and constructive simulators.

More recently, US Army STRICOM created a program called Embedded Training for Dismounted Soldiers (ETDS) (Dumanoir et. al. 2002). One of the focus areas of this program was to use wearable computers to provide AR- and VR-based training in the field, yielding the MARCETE system (Kirkley et. al. 2002) which integrates an AR system with SCORM datasets, and VICTER (Barham et al. 2002), which was built to fit within the limitations of the current Land Warrior system (Natick Soldier Center 2001), replacing pieces of that system as necessary.

Our own previous work, partially funded through the ETDS program, includes a system for Military Operations in Urban Terrain (MOUT) training, allowing a dismounted trainee to navigate a building and see and engage virtual and constructive enemy forces in the real world (Brown 2004). That goal was very ambitious and yielded a proof-of-concept system that was several years from being fielded. The primary roadblocks are tracking accuracy for mobile applications and field readiness of wearable computers that are powerful enough to drive AR. With the FiST training application, we considered a problem for which a fieldable system can be built with existing components, that would benefit from the real-time combination of live, virtual, and constructive forces, and that no one else has yet addressed.

APPLICATION OF AUGMENTED REALITY FOR FIRE SUPPORT TEAM TRAINING

One of the goals of this undertaking was that the AR system should support the current training paradigm. The purpose of the first stage is to hone communication skills and not train for absolute accuracy in call-for-fire. Therefore, the instructor has the final authority over the success or failure of any particular mortar firing. For example, the instructor may have a trainee repeat a fire, even if it was a direct hit, to reiterate the communications skills learned.

Integration of AR into the Training Plan

The AR system, based on the Battlefield Augmented Reality System (Livingston et. al. 2002), consists of two stations networked together: a head-mounted display for the forward observer and a touch screen display for the instructor. Each shows the same set of virtual targets superimposed on the real range. The observer station simulates a view through a pair of binoculars and can provide a magnified view (including a reticle) to determine target identity and grid coordinates. The instructor station uses a camera in a fixed location to provide an overall view of the range. The instructor can start and stop the movement of targets and determine the effect of a fire through a simple menu system and directly selecting objects on the display.

The order of events is illustrated in Figure 2. First, the forward observer, wearing the AR HMD, observes and identifies a target, and determines its grid coordinates. Figure 3 shows a typical view of the virtual targets overlaid on the real world. Next, the observer calls for fire, reporting the target to the Fire Direction Center (FDC); in the training, the instructor also plays the role of the FDC. The FDC sends an order to the mortar operator, who fires a real (pneumatic) round at the training area. The instructor looks at where the round landed in the real field and on the augmented display, as shown in Figure 4. The rounds are hard to see after landing on the field, so an assistant marks the round with a pole. The instructor makes a judgment call

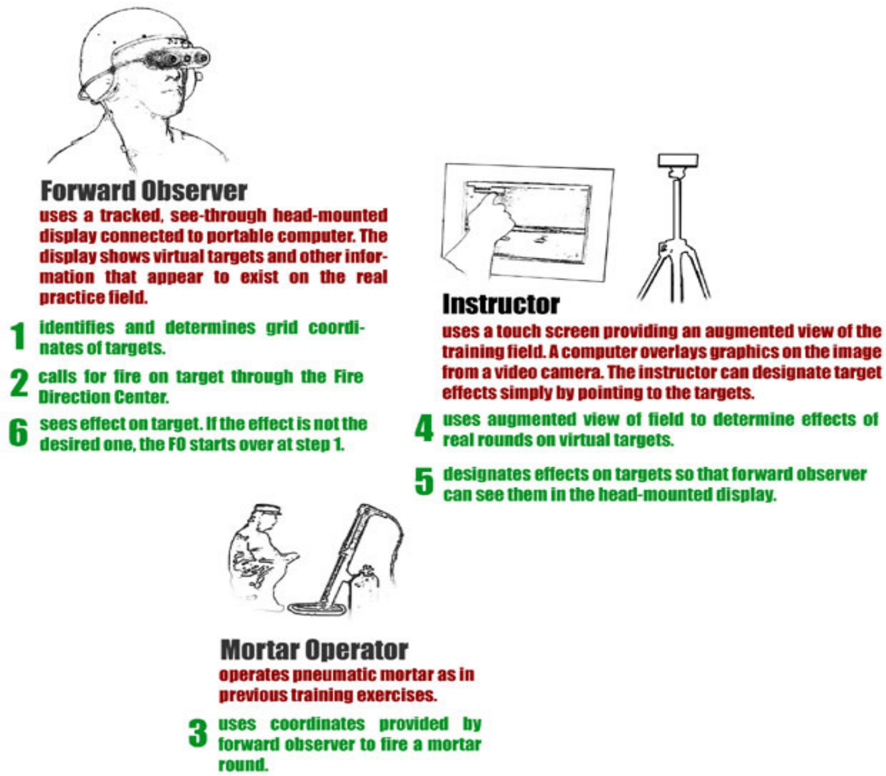

Figure 2. Order of events using the AR system in training

Figure 3. An augmented view of the training area.

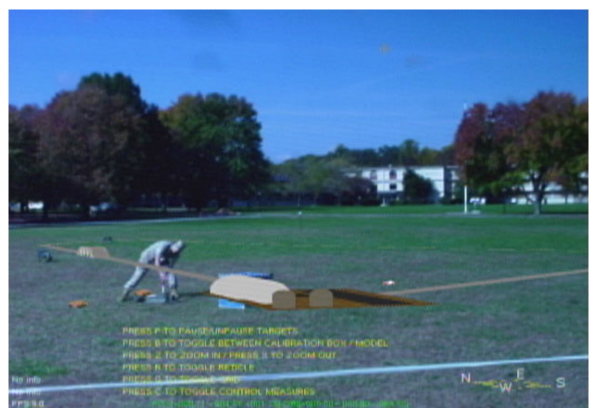

Figure 4. An assistant marks where round landed.

Figure 5. The real round was determined to have destroyed the virtual target.

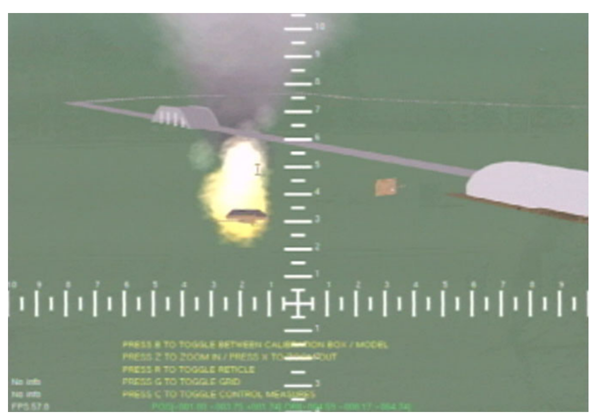

Figure 6. A zooming feature allows one to identify the target.

about the effect on the target and can designate that on the touchscreen display—Figure 5 shows a direct hit on the target. Finally, the observer immediately sees the designated effect on the target in the HMD, and can even zoom in on the virtual targets for a closer look, as shown in Figure 6 (the video background is replaced by a solid green background due to technical limitations with the hardware in use at the time; future versions of this system will scale the video as well).

System Component Description

The *observer* wears a helmet-mounted HMD, as seen in Figure 7, to provide a tracked, augmented view of the training area. This HMD is connected to a laptop computer that drives the visuals. The HMD contains cameras just ahead of the user's eyes that collect video to be augmented. On the rear of the HMD (not visible in Figure 7) sits a rear-facing camera used for high-precision video-based tracking—this camera captures images of a set of graphical markers placed behind the user and calculates the position and orientation of the user's head. With the high-precision tracking, the user can look all around the training area and the virtual targets appear to remain fixed in the real world. The user interface consists of just three operations: controlling the zoom level, turning the reticle on and off, and turning a virtual grid on and off. The observer's portion of the system is simple to operate and allows the trainee to concentrate on the task and not the equipment.

Figure 7. The trainee wears a head-mounted display to see the virtual targets.

The *instructor* uses a station with a large, bright touch screen attached to a laptop computer. The instructor can start and stop the virtual targets, designate effects on the targets, and reset the simulation, through a few options on the touch screen display. Again, the focus was on simplicity: when the instructor wants to designate an effect on a target, he selects the effect

Figure 8. The instructor's station.

from a menu and touches the target directly. This station also has a fixed camera with a wide field of view that collects video from the training area and sends it to the computer to perform the augmented overlay. Figure 8 shows the instructor's station as used in the demonstration (as well as the laptop used to drive the observer's display and some extra equipment used for post-demonstration testing and evaluation). Figure 9 shows the instructor designating an effect on a virtual target using the augmented touchscreen display.

For this demonstration, all equipment was loaded onto a handcart and powered by large batteries. We chose this path to keep the demonstration running all day and to accommodate a lot of attendees wanting to try the system—it's a lot easier to put on a helmet than an entire wearable backpack. The observer's training system can easily run on the wearable backpack shown earlier in Figure 1, while the instructor station can be "compacted" onto a single tablet PC with an attached camera.

Figure 9. The instructor designates an effect on a virtual target.

Software Description

As mentioned previously, the software was based on the Battlefield Augmented Reality System developed in our lab. The BARS libraries were used to provide the augmented reality core components including tracker drivers, display calibration, and video overlay. Through a dynamic shared database in BARS (Brown et. al. 2004), the virtual targets, controlled by the instructor's computer, are also updated in real time on the observer's computer. Similarly, it is this mechanism by which the observer sees the effect on the target determined by the instructor.

For this particular application, we added a few new features to enhance the training experience:

- Virtual grid: The observer can turn a virtual grid on and off. This grid is drawn on the ground plane and is spaced at simulated 1km intervals (25m actual).
- Terrain: The observer can turn virtual towns, roads, and other artifacts on and off.
- Zoom: As mentioned previously, the observer can zoom in on the virtual targets.
- Reticle: Also as mentioned previously, the observer can turn a virtual reticle on and off to more accurately determine the location of a target. If the reticle is turned on while zooming, it is automatically scaled to fit the screen and allow the observer to accurately calculate angles.

One of the primary features of training in the real world using augmented reality is the ability to model the real world training area and properly occlude virtual entities as they move through the environment. In the case of this particular training area, because it was a flat field, there were no significant terrain features to model. To demonstrate occlusion capabilities, we placed a shipping crate in the field and added it to the AR occlusion model. Figure 10 shows a virtual tank (drawn at the same 1:40 scale explained previously) properly occluded by the real-world box. One can easily imagine this box is a real building, and this concept can be extended to full-scale hilly or mountainous training areas by creating an occlusion model from DTED or similar data.

Figure 10. A real-world object (blue box) occludes a virtual tank and truck.

CONCLUSION

Augmented Reality was inserted into the training plan with no significant changes to the duties and actions of the participants, except that they can now fire on moving targets. The virtual targets for training were well received by the mortar trainees and instructors at Quantico. One USMC captain said:

> The Marine Corps will always rely on live training as the cornerstone for preparing ourselves, but simulation and this type of augmented reality will help make training more effective and more realistic to live combat. As we look to develop requirement documents for range instrumentation and improved MOUT facilities, AR will be a technology that we incorporate into the appropriate aspect of the training facilities.

However, rigorous studies and measurements of effectiveness are yet to be done. The system can also insert virtual terrain and control measures into the display, and both capabilities were preliminarily tested at Quantico. Future plans include refining the system, using multiple and/or pan-tilt-zoom cameras, implementing the system at a full-scale live fire range such as Twentynine Palms, and completing a Semi-Automated Forces (SAF) interface for more intelligent targets.

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